AD 697 824

THE RELATIONSHIP BETWEEN A COMPLEX OF RADAR CHARACTERISTICS OF CLOUDS AND OF THE ATMOSPHERE AND THE FORM OF THE PRECIPITATION REACHING THE EARTH

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25 September 1969

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TRANSLATIONS

AD 697824

CLB-3 T-607 25 September 1969

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Translated from

Meteorologiya i Gidrologiya
[Meteorology and Hydrology]
No. 4, pp. 84-86 (1969)

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C. R. Haave

Summary

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THE RELATIONSHIP BETWEEN A COMPLEX OF RADAR CHARACTERISTICS OF CLOUDS AND OF THE ATMOSPHERE AND THE FORM OF THE PRECIPITATION REACHING THE EARTH*

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Advances in the field of radio meteorology allow us to make operational measurements of some accuracy of certain micro-structure characteristics of clouds; this opens up a broad vista for investigating the formative processes of clouds and precipitation.

In recent years many papers have appeared dealing with radar methods for defining the forms of precipitation falling to earth [1-3 and others]. In these papers primary emphasis is placed on establishing the correlation between the radar returns and the type and size of the precipitation or on ascertaining the probabilities of the various forms of precipitation.

In this paper we attempt to establish a relationship between the type of precipitation, a complex of radar characteristics and the thermal state of the lower layers of the atmosphere.

The following parameters were used to establish this relationship:

— the ratio of the radar returns at two wavelengths;

— the power from the super-cooled portion of the radar return;

— the power from the warm portion of the atmsophere (distance between the earth's surface and the level of the zero isotherm).

It is shown in reference [1] and others that the mean cubic size for different particle spectrum models can be determined from the ratio of the radar returns at two wavelengths $\eta_{\lambda_1}/\eta_{\lambda_2}$ from a certain volume of the cloud being studied. From the magnitude of $\eta_{\lambda_1}/\eta_{\lambda_2}$ one can with confidence make a judgement

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whether large-scale or fine particles fill the volume of cloud being investigated or the precipitation.

The power in the super-cooled portion of the radar return (H_-) is the most comprehensive cloud parameter describing the thermal state of the cloud. This parameter contains not only information on the thermal state of the cloud but also information on the nature of certain processes within the cloud.

To allow for the melting and evaporation of particulate precipitation falling from the cloud requires the introduction of a parameter to characterize this process. Such a parameter is the power of the warm portion of the atmosphere.

It is known that the processes of melting and evaporation and the final size of the precipitation reaching the earth depend on the initial mass (size) of the particles and on other factors. Therefore we did not simply introduce the value of the power of the warm portion of the atmosphere that characterizes the melting temperature, the time of melting as a function of the path of fall, the water content of the near-earth layers of air as a function of temperature, etc., but used the ratio of the power of the warm portion of the atmosphere (H_+) to the power of the supercooled portion of the radar echo (H_-). This ratio shows the relationship existing between the processes of formation and growth of one or another particle and the processes of melting and evaporation of these particles.

Further analysis to ascertain the form of the precipitation assumes the construction of a nomogram in a coordinate system that would involve the described cloud and atmosphere parameters in relation to the form of precipitation. In our opinion a nomogram in the system of coordinates ($\eta_{\lambda_1}/\eta_{\lambda_2}$; H_+/H_-) meets the requirements.

Regions of rainfall, snow-graupel, hail may be separated on this nomogram.

1. If the cloud is almost entirely located in the warm portion of the atmosphere, $H_- \to 0$ and the ratio $H_+/H_- \to \infty$. Thus, with certain large values of H_+/H_-, no matter what the value of $\eta_{\lambda_1}/\eta_{\lambda_2}$, it can be anticipated that all precipitation reaching the earth will be in liquid form.

2. If $H_+ \to 0$, then $H_+/H_- \to 0$. In this case, only solid precipitation in the form of snow or graupel will reach the earth, no matter what the ratio of the radar reflectivities, since with low temperatures in the atmosphere there is insufficient moisture for a strong development of clouds and the formation of

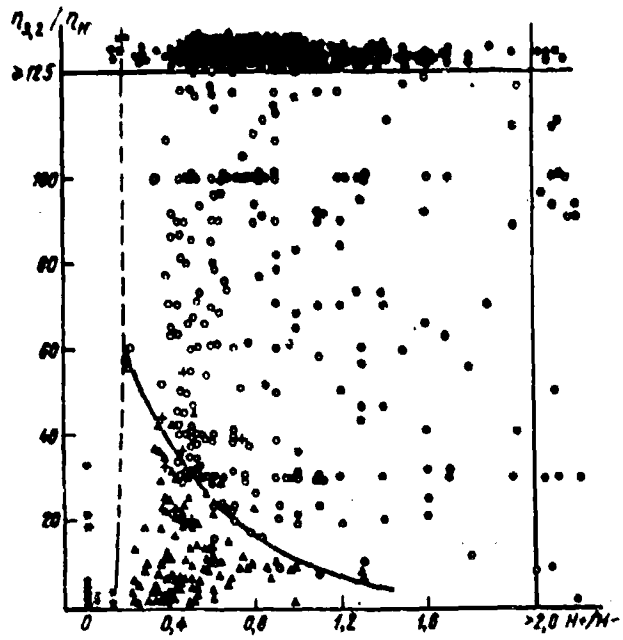

Figure 1. The relationship between the ratio of the radar reflectivities at $\lambda_1 = 3.2$ cm and $\lambda_2 = 11.0$ cm, the ratio of the powers of the warm and supercooled portions of the radar return and the type of precipitation.

zones of high water content in a cloud, where very dense and large-size ice hail-aggregates could be formed.

3. According to [1], with large values of $\eta_{\lambda_1}/\eta_{\lambda_2}$ very small particles exist in the cloud; depending on the value of H_+/H_- they may fall to earth in the form of snow and graupel (with $H_+/H_- \to 0$) or as rain (with $H_+/H_- \gg 0$).

4. In a region bounded by certain optimal values of the ratio of $\eta_{\lambda_1}/\eta_{\lambda_2}$ to H_+/H_- precipitation in the form of hail may be expected.

Specific boundaries of this region must be established experimentally.

Figure 1 illustrates the nomogram for the relationship between the type of precipitation reaching earth and the ratio of the radar reflectivities at two wavelengths ($\lambda_1 = 3.2$ cm, $\lambda_2 = 11.0$ cm) and the ratio of the radar return power from the warm portion of the atmosphere to that from the supercooled portion. The circles indicate cases of rainfall, the triangles refer to hail and the asterisks denote graupel.

The nomogram was drawn up using data from radar, aerological and meteorological observations made during 1965-1967 by the Caucasus group of the hail-prevention expedition, which operated in the territories of Armenian SSR, Georgian SSR and Kabardino-Balkar ASSR and the Servo-Osetin ASSR and the Stavropol and Krasnodar regions. In all we examined about 700 measurements during precipitation.

The measured data were treated as follows. On days when clouds and precipitation from them were observed, the radar sets made measurements over short periods of time on zones in which meteorological targets were detected. Measurements of the following quantities were made: maximum reflectivity at 3.2 cm and 11 cm; altitude of upper edge of the radar echo as measured by the 3.2-cm radar, time of measurement and the coordinates of the cloud on which the measurements were made. The radar observations were then tied to place and time in accordance with these data, and later, on the basis of a check tour of the territory, meteorological observations and inquiries of the inhabitants, the facts regarding the form of the preciptation were established. If it was not possible to ascertain reliably the time of fall of some form of precipitation, the radar data were not used.

The ratios $\eta_{3.2}/\eta_{11}$ and H_+/H_- were computed from data selected as indicated above. The power of the supercooled portion of the return was established from the difference between the upper edge of the radar return and the level of the zero isotherm. The altitude of the zero isotherm was established according to data from a radiosonde that was launched at a time close to the time of the radar measurements. The radiosonde launch point was usually not farther than 100 km from the area of precipitation being investigated. Then each case of radar measurement, thus processed, was plotted on the monograph form.

Clearly differentiated areas of solid and liquid precipitation, and in the area of solid precipitation zones of hail and snow (Figure 1), are evident on the nomogram. The scatter of points falling in non-correlated regions is insignificant. Thus, beyond the line of demarcation, in the region of solid precipitation, liqiud precipitation is observed in about 8% of the cases, and solid precipitation occurs in the region of liquid precipitation in about 3% of the cases. Further study of the physical processes of the formation of precipitation should allow deriving a more reliable correlation.

The nomogram obtained by us would appear to be useful in efforts to influence hail clouds.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) The Johns Hopkins University, Applied Physics Lab. 8621 Georgia Avenue Silver Spring, Md.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

The Relationship Between a Complex of Radar Characteristics of Clouds and of the Atmosphere and the Form of the Precipitation Reaching the Earth

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

V. S. Antonov and Kh. Kh. Medaliev

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
25 September 1969		

8a. CONTRACT OR GRANT NO. NOw 62-0604-c b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) CLB-3 T-607 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	NAVPLANTREPO Naval Ordnance Systems Command

13. ABSTRACT

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DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS

Radar meteorology

Detection of precipitation

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